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MECHANICAL PROPERTIES OF INCONEL X SHEET AT + 78, -100, -320, AND -423°F

MRG-150

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GENERAL DYNAMICS/CONVAIR

TO: Distribution

FROM: Materials Research Group, 595-2

SUBJECT: Mechanical Properties of Inconel X Sheet at +78, -100, -320, and -423° F

An evaluation of the properties of Inconel X sheet at ambient and cryogenic temperatures was undertaken due to an increased interest in the substitution of a high strength/density material with favorable low temperature properties for type 321 annealed stainless steel in the production of thrust rings, brackets, etc. Inconel X, a heat-treatable nickel-base alloy, offered many attractive features such as availability in many forms, good welding characteristics, good corrosion resistance, and moderately high tensile strengths. In order to ascertain the possible application of Inconel X at cryogenic temperatures, the mechanical properties (F_{ty}, F_{tn}, e, and notched/unnotched tensile ratios) of the base metal and resistance spot weld properties of Inconel X to 301 XFH stainless steel were determined at +78, -100, -320, and -423° F. Report MRG-134, "Evaluation of Inconel X to 301 Stainless Steel Resistance Spotwelds at 78° F and -423° F", presented data which showed that reliable, high strength resistance spot welds were obtained with Inconel X - 301 XFH stainless steel sheet materials at both room and very low (-423° F) temperatures.

In the present report Table 1 gives the chemical composition limits of Inconel X and Table 2 the typical mechanical properties of annealed and heat treated material in various available forms (sheet, plate, rod and bar, strip, castings, tubing, and wire). Table 3 presents data generated by the Materials Research Group on 0.063-inch Inconel X sheet, solution treated and aged, as a function of temperature (78, -100, -320, and -423° F).

The relatively high yield strength (118 ksi, 0.2-percent offset at 78° F) of the solution treated and aged Inconel X sheet makes this material look most favorable in comparison to 321 annealed stainless steel which has a design allowable yield strength of 30 ksi. Since the densities of these two materials are nearly the same (0.29 lb/in.^{3} for 321 and 0.30 lb/in.^{3} for Inconel X), the strength-to-weight ratio of Inconel X is at least three times that of type 321 CRES. A significant increase in yield strength is also realized at lower temperatures (134 ksi at -423° F). The Inconel X sheet material also exhibits high ultimate tensile strengths (174 ksi at 78° F and 233 ksi at -423° F), with very good ductility (25.0 to 31.0 percent) as measured by elongation at all testing temperatures. The proportional limit is 95 ksi at 78° F and higher at reduced temperatures. The notched/unnotched ratio, a criterion of brittle fracture, is somewhat low (0.85 at lower temperatures); however, its metallurgical similarity to K-Monel which has proved satisfactory for cryogenic applications in the Atlas missile system (LOX lines, valves, ducts, etc.) warrants further consideration and resulting development of Inconel X

for subzero temperature use. The fact that the notched tensile strength significantly increases with reduction in temperature (168 ksi at 78° F to 200 ksi at -423° F) is indicative of favorable crack resistance at low temperatures.

Several specimens of Inconel X in the as-received condition (annealed, from 1900 to 2100° F) were tested, but the low yield strength (47 ksi at 78° F) practically eliminates the use of Inconel X in this condition except in those cases where an aging treatment is not practicable. Normal heat treatment of Inconel X for applications at 1100° F or less is annealing (1900 to 2100° F) followed by aging (1300° F/20 hr, and air cooled).

Present data indicate that the favorable subzero mechanical properties of the base metal and the reliable, high-strength resistance spot welds (to 301 CRES) of Inconel X makes it a candidate material to replace type 321 CRES for thrust ring applications.

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Table 1. Chemical Composition Limits of Inconel X*

	Wrought	Cast
Nickel	72.0 minimum	Remainder
Chromium	14.0 - 17.0	14.0 - 17.0
Iron	6.0 - 10.0	11.0 maximum
Manganese	1.0 maximum	1.50 maximum
Copper	0.50 maximum	-
Silicon	0.50 maximum	3.0 maximum
Carbon	0.15 maximum	0.40 maximum
Sulfur	0.015 maximum	-

*From International Nickel Company, Bulletin T-7

Table 2. Mechanical Property Ranges of Standard Forms*

Form and Condition	F_{ty} (0.2%) ksi	F_{tu} ksi	e %
Sheet, cold-rolled			
Annealed	30 - 45	80 - 100	55 - 35
Hard	90 - 125	125 - 150	15 - 2
Age-hardened**	100 minimum	155 minimum	20 minimum
Plate, hot-rolled			
Annealed	30 - 50	80 - 105	55 - 35
Rod and bar			
Cold-drawn	80 - 125	105 - 150	30 - 10
Hot-rolled	35 - 90	85 - 120	50 - 30
Age-hardened#	92	162	24
Strip			
Annealed	30 - 45	80 - 100	55 - 35
Spring temper	120 - 160	145 - 170	10 - 2
Castings, as cast	30 - 45	70 - 95	30 - 10
Tubing, cold-drawn			
Annealed	30 - 45	80 - 100	55 - 35
Wire, cold-drawn			
Annealed	25 - 50	80 - 105	50 - 25
Tempered	115 - 165	130 - 175	12 - 3

*From International Nickel Company, Bulletin T-7
**Annealed (1900 - 2100° F), aged 1300° F/ 20 hr, and air cooled
#Solution treated 2100° F/4 hr, aged 1550° F/24 hr, and 1300° F/20 hr, and air cooled

Table 3. Mechanical Properties of Inconel X
0.063-Inch Sheet, International Nickel Co.,
AMS5542, Heat No. 3415X, Solution Treated and Aged

Test Temp °F	Direction	F_{ty} ksi	F_{tu} ksi	e %	Notched T.S. (K_t = 6.3) ksi	Notched/ Unnotched Tensile Ratio
+78	Long.	117	174	25.0	169	
	Long.	118	174	25.5	167	
	Long.	118	174	26.0	168	
	Avg	118	174	25.5	168	0.97
+78	Trans.	118	174	25.5	168	
	Trans.	118	173	25.0	168	
	Avg	118	174	25.0	168	0.97
-100	Long.	123	190	31.0	174	
	Long.	120	188	30.0	175	
	Long.	122	190	29.0	174	
	Avg	122	189	30.0	174	0.92
-100	Trans.				174	
	Trans.				176	
	Avg				175	-
-320	Long.	129	215	31.0	186	
	Long.	131	214	31.0	186	
	Long.	131	213	31.5	181	
	Avg	130	214	31.0	184	0.86
-320	Trans.	130	212	33.0	183	
	Trans.	130	212	27.0	185	
	Avg	130	212	30.0	184	0.87
-423	Long.	134	232	29.0	207	
	Long.	135	235	31.0	200	
	Long.	134	232	30.0	189	
	Avg	134	233	30.0	199	0.85
-423	Trans.	139	233	30.0	205	
	Trans.	-	234	32.0	197	
	Avg	139	234	31.0	201	0.86